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# EDUCATIONAL PLATFORM TO TEST AUTOMATION SYSTEMS IN COMBUSTION ENGINES

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**ABSTRACT**

Laboratory practices are important components of any engineering curriculum. The laboratory is an important tool for the engineer to the student makes possible the learning of practical aspects of their profession. Several discussions on types of experiments, correlation between laboratory and class work, importance of the laboratory in the general curriculum and others. It has been a general consensus that laboratories are essential and should be included in the curriculum. Promote practices that ensure a better quality of teaching by developing critical thinking are the main concerns in the ongoing development plan of the laboratories of the engineering department.



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## INTRODUCTION

The growing demand for postgraduate courses that specializes newly graduates or are already working in the labor market is growing. To increase the theoretical teaching of graduate courses associated with practice, it is necessary to use compatible laboratories with the contents adopted in these courses. According Guzman-Ramirez et al. (2015). Knowledge is obtained through experimentation. Therefore, the practical knowledge is an important requirement for these professionals, and improve their practical skills, universities and technical schools apply teaching methods based on experimentation exclusively offer lectures (Stankovski, 2010). Private institutions also seek to improve their students with practical lessons. The industry constantly pressing educational institutions to form automation technicians with sufficient knowledge and basic experience for the formal and / or informal, is kept to a minimum acceptable standard.

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Consequently, there is a need to provide materials and learning content that are relevant to the industry and update them and modify them continuously to adapt industrial equipment (Dormido, 2008). Laboratory practices allow students to apply abstract or theoretical knowledge obtained in lectures to develop their understanding through these practices (Geaney, 2015). Laboratory experiments offer one way to introduce more realism into the education of automatic control (Astrom, 1986). The initial orientation in the laboratory is a crucial step. Recognizing that learning is best achieved in an environment where students feel calm and secure, initial exercises are employed to familiarize students with the laboratory protocols (Dalgarno, 2012). The laboratories are an integral part of the development of control systems, they motivate the analytical development and reinforce key concepts (Heath, 2013). The laboratories play a very important role in improving the practical knowledge of students and their in-depth understanding of the theoretical lessons, providing practical experience (Thomas, 1999). It is essential that students have access to practices which apply theoretical concepts effecting learning, allowing the generation of knowledge. It is becoming more constant than the segments of industrial production, power generation and distribution, logistics and many others, increasingly rely on new systems and automated machinery. This is due to increased productivity, lower the costs of automation components and machines, the ease of use of new technologies, quality and stability of new products and the need to replace dangerous and monotonous work of operators (Ribeiro, 1999). This paper describes a laboratory and its practical application, enabling the development and competence of students in designing and developing programs with programmable logic controllers (PLC) applied to power generation environments. PLC's are computers designed to operate in industrial environments and for their operation, they have one part of hardware and another part software (Rodríguez, 2018). To illustrate the importance of laboratory use in learning, it was specified and developed hardware and software for monitoring quantities combustion pressure and temperature and water pressure in a power generator simulating the operation of a power plant.

**Problem statement:** The power generation test lab and automation is a collection of mechanical instruments and automation components, which provides students tools to specify and develop systems for monitoring and control. The student can build independent programs in *Arduino* and *LabVIEW*. The objective and exemplify the use of these systems and equipment.

**Laboratory overview**

**Laboratory Description:** The teaching laboratory used is a small-scale laboratory designed for Engineers, Computer Scientists researchers from the Galileo Institute of Technology and Education of the Amazon (ITEGAM) and postgraduate students of the Federal University of Pará (UFPA), it allows you to run experiments different control systems and artificial intelligence techniques at the same time. Figure 1 display the suggested components for the proposed lab for simulation and cooling combust.

Source: [11]

**Figure 1. Front view of the pilot laboratory described in this section**

The simulation lab is divided into the following structures:

- Mechanical prototype, which was installed pressure sensors and the cooling water temperature of the combustion system displayed in Figure 2;

Source: [11].

**Figure 2. Mechanical prototype**

- Control panel is part of the system and facilitating simulations of operations and working conditions and pressure changes and temperature of the cooling water to be monitored, displayed in Figure 3.

Source: [11].

**Figure 3. Control Panel**

The control panel has push buttons, monitor and keyboard for use with DeskTop CPU or Notebook through this panel it is possible to simulate:

- Operation of the cooling water within the ducts circulção;
- System cold water;
- Hot water system;
- Compressor 1 simulates the normal pressure in the system;
- Compressor 2 simulates the sudden change in the system;

The prototype built allows the simulation of the pressure and temperature of the cooling water in the combustion engine cylinder. The quantities that can be analyzed in the process are: air pressure, water pressure and water temperature.

The reading specifications for each magnitude are:

- Air pressure: 0 to 20 bar
- Water pressure: 0 to 10 bar

- Water Temperature: 0 to 90$^0$C
- valve switching module for simulating the shape of cylinder liner prototype system and the work head. In addition to showing the run, the data are generated pressure and temperature of cooling water, visualized in Figure 4.

Source: [11]

**Figure 4. Valves switching module**

- Hot water system, the system will operate using a thermo-regulator to simulate the heating of the water when it performs the prototype mechanical cooling. Thus it is possible to generate the temperature data of the water, the installed system provides hot water with pressure to the cylinder. This term regulator has a small water pump, a reservoir with electric heater for adjusting the temperature of cooling water, visualized in Figure 5.

Source: [11]

**Figure 5. Hot water system**

- The compressor 1 is used to perform the simulation of the input gas into the cylinder. This compressor that injects air chamber to a pressure of 20 bar. This data is captured by a pressure transducer, seen in Figure 6.

Source: [11]

**Figure 6. Compressor 1**

- The compressor 2, simulates enters from the combustion gas within the cylinder water chamber in order to simulate the turbulence which can occur by failure or malfunction of the head of the sealing ring, viewed in Figure 7.

Source: [11].

**Figure 7. Compressor 2**

- Cold water pumping system is used in the prototype mechanical cooling cylinder liner and cylinder head, seen in Figure 8.

Source: [11].

**Figure 8. Cold water pumping system**

**Sensors Used**

**Pressure Sensor**: The Pressure Transmitter High Temperature VKP-027, IP65 is designed to meet industrial applications and solve the high temperature challenges accurately and efficiently. Its construction is entirely in AISI316L, its design in the form finned increases air contact area causing the heat dissipation happen. The degree of protection is IP65 ensuring total protection against dust and water jets in any direction. The subsidiary microelectronics is composed of SMD components of high quality and has the unique technology of temperature compensation, which makes it the best choice for different industry demands.

**Sensor measuring the water pressure:** The Mini Pressure Transmitter has the most compact design on the market. It is designed to meet industrial applications and meet the challenges of small spaces with precision and efficiency. Its construction is according to AISI 316L specification, which makes it compatible with most industrial processes.

**Temperature measurement sensor**: Type K Thermocouple is the most commonly used thermocouple because caters to a wide variety of probes that make measurement from -200 ° C to 1350 ° C. The thermocouple type K can meet a wide range of needs in the industry. In this case it is used for monitoring the cooling water temperature.

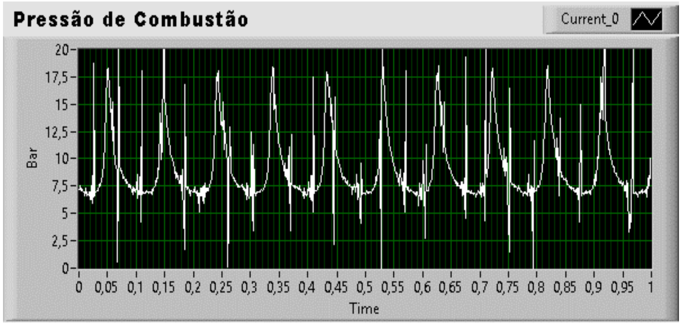
**Table 1. Presents the data from sensors used in the laboratory**

| Description | Specification |
|---|---|
| Pressure Sensor | VKP-027, IP65 |
| measuring water pressure sensor | Mini VKP-011. IP65 |
| Temperature measurement sensor | Type K Thermocouple |

**Proposed projects:** The Laboratory practices of the combustion laboratory automation and represent 40% of the lectures. The courses are entirely based on projects developed with a cognitive practical approach. The laboratory allows students to develop simultaneous experiments. They are created groups of students who should develop projects to control the monitoring of the combustion pressure and temperature and water pressure. At the end of the course, each group responds to an evaluation of aspects of the discipline and practices developed in the laboratory.

## DISCUSSION

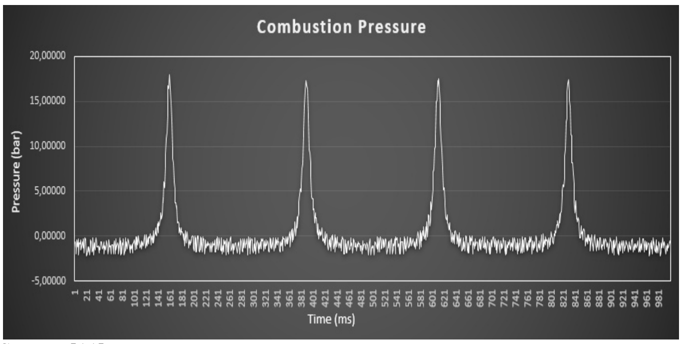
A small-scale combustion laboratory will be used as a teaching tool at the Galileo Institute of Technology and Education of the Amazon - ITEGAM for teaching subjects such as electrical machinery, industrial automation, smart grids. Through which students of electrical engineering and automation will be encouraged to develop practical projects. To measure performance the use of laboratory and the research, reports will be prepared on each experiment at the end of each project. The magnitudes monitored in the first tests, were the air pressure within the cylinder aimed at stimulating the process of combustion pressure and temperature of the cooling water. The capture of information concerning the variation of the magnitudes is performed through the interface between the prototype and software. Said interface is the Digital to Analog converters (DA) of the National Instruments® designed for this purpose. The compound prototype of the shirt and the actual head has a cavity closed between the two elements of the engine to which the air is injected, by measuring the disturbances within said cavity, which to some extent simulates the changes in combustion pressure, though they are not the same as those made in field tests in a real engine, allow you to test the sensitivity and variations using the software, on the other hand. Once the sensor has been mounted and the information was collected through the corresponding software, the results of a real engine in laboratory scale are presented in the remainder of this work. In this case the pressure of the combustion was tested leaving the test pressure and water temperature to the preliminary tests. Each preliminary test was carried out in stages in order to check the operation of software and the accuracy of the results. Each preliminary test is a demonstration of the truth of the software. In Figure 9, the combustion pressure is displayed graph in the real generator.




Source: [11].

**Figure 9. Combustion pressure in Real Generator laboratory**

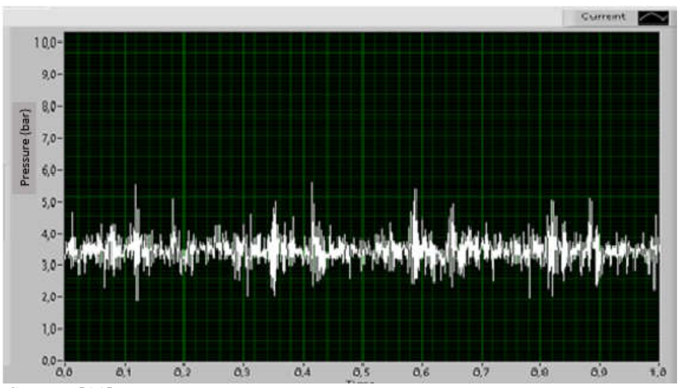
Figure 10 shows a graph of the combustion pressure in the laboratory prototype by software simulation.




Source: [11].

**Figure 10. Combustion pressure in laboratory prototype**

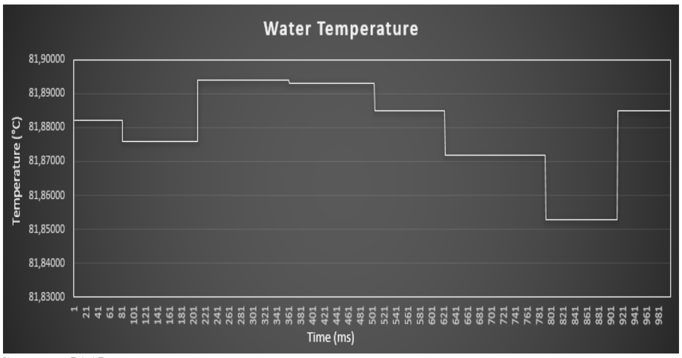
In Figure 11, the graph is displayed the cooling water pressure in the laboratory prototype.




Source: [11].

**Figure 11. Cooling water pressure in the laboratory prototype**

In Figure 12 is shown the graphic temperature of the cooling water in the laboratory prototype by software simulation.




Source: [11].

**Figure 12. Cooling water temperature in the laboratory prototype**

As can be seen in the above graphic, the results are satisfactory according to the parameters indicated by the manufacturer in relation to the characteristics and behavior of the combustion process, pressure and temperature of the water that are recorded by the said process monitoring through software developed for this purpose. Any departure from the normal generator operating values could also be observed, becoming these values in diagnostic parameters that would be a clear sign of an abnormality in the functioning of the generator, which would allow to take the necessary steps at the right time. As noted, the amounts of cooling water pressure will be in the range of 3 to 4 bar and the water temperature around 80 degrees in the output. The observed deviations of these values were in accordance with the graphics that are specific conditions and they are not permanent conditions that may indicate leakage of combustion gases toward the cooling water or to the water into the cylinder. Although the values are not exactly constant, they remain within the established range. It should be noted that there is an influence of factors such as noise or vibration or any scale that arise as a result of continuous operation, a situation that may be present in these facilities, which have an influence also in the form of graphics. The explanation allows to clearly understand that from the monitoring of these conditions can detect problems, among them the most important deformation or breakage of the gasket between the cylinder block and the generator.

### Summary

In this work, the specification of the combustion and automation laboratory prototype is presented to practice the disciplines of engineering courses for students in general consolidating academic theoretical learning with practice. This approach uses an environment that provides equipment applications and systems for learning about the operating conditions of the generators. Students and teachers can use these devices as parameters for applied studies implementations.

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